HSNA106 – Model META_LEMA_ANI: full cylinder in simple traction with variable temperature

Summary:

This quasi-static thermomechanical test consists in heating a cylindrical bar uniformly ($2D$ axisymmetric) then to subject it to a traction.

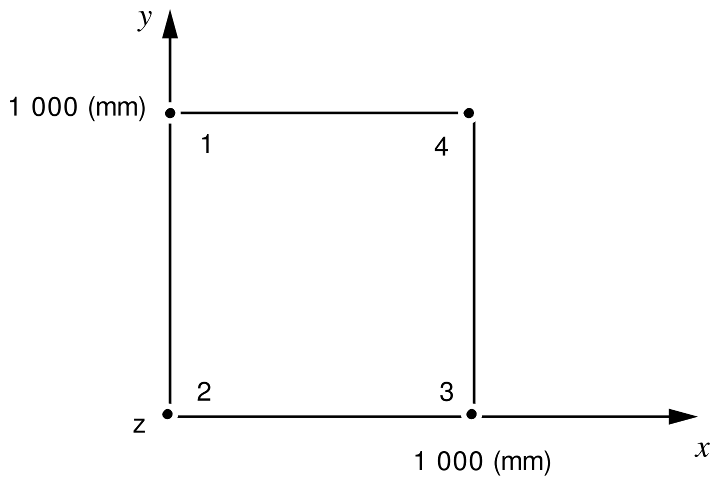
The bar is represented by a quadrangular axisymmetric element `QUAD4`. It is modelled in two different but equivalent ways: maybe with the model META_LEMA_ANI that one makes "degenerate" into a law of Norton by choosing in a judicious way the coefficients (modeling A), is with a law of Norton itself (modeling B).

Model META_LEMA_ANI comprises two different dilation coefficients thermal for the cold phase $\eta\alpha\sigma$ and the hot phase B. In the case more the general, dilation is calculated by a law of the mixtures. Here, one places oneself if there are 100 % of phase B and one tests the calculation of thermal dilation.

The thermomechanical loading is done in imposed displacement and imposing an increasing temperature. One must then obtain the same answer for two modelings A and B.

1 Problem of reference

1.1 Geometry



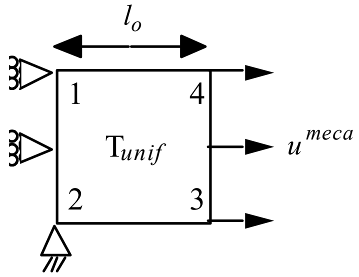
1.2 Properties of material

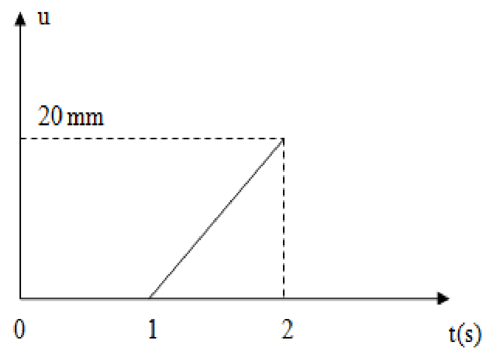
The material obeys a law of viscoplastic behavior of Norton (typical case of the law of Lemaître, where parameter UN_SUR_M is null, confer [R5.03.08]), whose parameters are:

- Young modulus: E = 80,000 MPa
- Poisson's ratio: ν =0.35
- N = 4.39
- $K=253.5497\, MPa\, s^{-1}$
- $\alpha=0.00004$

1.3 Boundary conditions and loadings

The bar, initial length l_o, blocked in the direction $O\mathbf{x}$ on the face [1.2] is subjected to a uniform temperature T and with a mechanical displacement of traction U on the face $[3,4]$. The sequences of loading are the following ones:





The imposed temperature is, in °C: T=1200+300t

Temperature of reference: $T_{réf}$ = 1200°C.

2 Reference solution

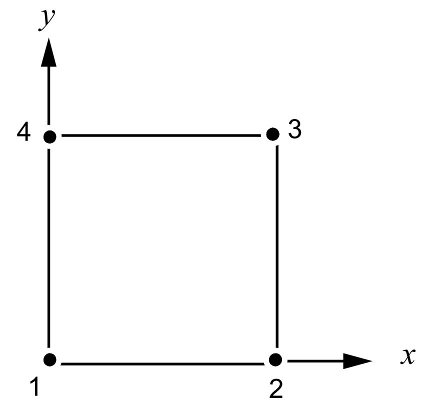
Validation of the law META_LEMA_ANI is done by the comparison of two modelings A and B.

Each of two modelings thus constitutes a reference solution for the other.

3 Modeling A

3.1 Characteristics of modeling

Modeling $2D$ axisymmetric: 1 mesh QUAD4
1 mesh SEG2



Boundary conditions:

$N1$: $U_y = 0$

$N2$: $U_y = 0$

Loading:

Traction on the face $[3\ 4]$ (mesh SEG2) + assignment of the same temperature on all the nodes
The full number of increments is of 20 (10 increment enters $t=0\text{s}$ and 1s, 10 increments enters $t=1\text{s}$ and 2s)

Convergence is carried out if the residue RESI_GLOB_RELA is lower or equal to 10^{-6}.

Behavior:

For mechanical calculation, one uses the keywords ELAS_META and META_LEMA_ANI, with the following parameters (see [R4.04.05]):

$E=80\,000\ MPa$
$\nu=0.35$
$\alpha_f=0.$
$\alpha_c=0.00004$
$a_3=253.5497\ MPa$
$m_3=0.$
$n_3=4.39$
$Q_3=0.\ K$
$M^3_{rrrr}=1.$
$M^3_{\theta\theta\theta\theta}=1.$
$M^3_{zzzz}=1.$
$M^3_{r\theta r\theta}=0.75$
$M^3_{rzrz}=0.75$
$M^3_{\theta z\theta z}=0.75$

Parameters corresponding to phases 1 and 2 (respectively phase cold and mixes $\alpha\beta$) do not play of role and are taken unspecified.

3.2 Characteristics of the grid

Many nodes: 4
Many meshs: 2

1 QUAD4
1 SEG2

3.3 Sizes tested and results

The constraints and the deformations are compared compared to modeling B.

Identification	**Reference**	**Type of reference**	**Tolerance**
$t=0.3$ Constraints $SIGYY$ ($N3$)	-91.7598	Autre_Aster (modeling B)	1.00 %
$t=0.8$ Constraints $SIGYY$ ($N3$)	-92.5802	Autre_Aster (modeling B)	1.00 %
$t=1.3$ Constraints $SIGYY$ ($N3$)	70.1846	Autre_Aster (modeling B)	1.00 %
$t=2.0$ Constraints $SIGYY$ ($N3$)	84.4144	Autre_Aster (modeling B)	1.00 %

Identification	**Reference**	**Type of reference**	**Tolerance**
$t=1.3$ Total deflections $EPSYY$ ($N3$)	0,006	Autre_Aster (modeling B)	0.000001
$t=2.0$ Total deflections $EPSYY$ ($N3$)	0.02	Autre_Aster (modeling B)	0.000001

Identification	**Reference**	**Type of reference**	**Tolerance**
$t=1.3$ Plastic deformations $EPSYY$ ($N3$)	-0.0104773071226	Autre_Aster (modeling B)	0.000001
$t=2.0$ Plastic deformations $EPSYY$ ($N3$)	-0.00505515920024	Autre_Aster (modeling B)	0.000001

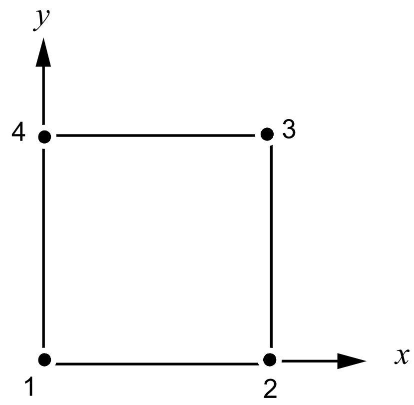
Identification	**Reference**	**Type of reference**	**Tolerance**
$t=0.8$ Thermal deformations $EPSYY$ ($N3$)	0.0096	Autre_Aster (modeling B)	0.000001
$t=1.3$ Thermal deformations $EPSYY$ ($N3$)	0.0156	Autre_Aster (modeling B)	0.000001
$t=2.0$ Thermal deformations $EPSYY$ ($N3$)	0,024	Autre_Aster (modeling B)	0.000001

Identification	Reference	Type of reference	Tolerance
$t=1.3$ Mechanical deformations $EPSYY$ ($N3$)	-0.0096	Autre_Aster (modeling B)	0.000001
$t=2.0$ Mechanical deformations $EPSYY$ ($N3$)	-0,004	Autre_Aster (modeling B)	0.000001

4 Modeling B

4.1 Characteristics of modeling

Modeling $2D$ axisymmetric: 1 mesh QUAD4
1 mesh SEG2



Boundary conditions:

$N1$: $U_y = 0$

$N2$: $U_y = 0$

Loading:

Traction on the face $[3\,4]$ (mesh SEG2) + assignment of the same temperature on all the nodes
The full number of increments is of 20 (10 increment enters $t = 0\text{s}$ and 1s, 10 increments enters $t = 1\text{s}$ and 2s)

Convergence is carried out if the residue RESI_GLOB_RELA is lower or equal to 10^{-6}.

Behavior:

The keywords are used ELAS and LEMAITRE, with the following parameters:

$$E = 80\,000\ MPa$$
$$\nu = 0.35$$
$$\alpha = 0.00004$$
$$n = 4.39$$
$$\frac{1}{K} = 0.003944$$
$$\text{UN\_SUR\_M} = 0.$$

4.2 Characteristics of the grid

Many nodes: 4
Many meshs: 2

1 QUAD4
1 SEG2

4.3 Sizes tested and results

The calculated deformations are used as reference to modeling A.

Identification	Reference	Tolerance
$t=0.3$ Constraints $SIGYY$ ($N3$)	-91.7598	1.00 %
$t=0.8$ Constraints $SIGYY$ ($N3$)	-92.5802	1.00 %
$t=1.3$ Constraints $SIGYY$ ($N3$)	70.1846	1.00 %
$t=2.0$ Constraints $SIGYY$ ($N3$)	84.4120	1.00 %

Identification	Reference	Type of reference
$t=1.3$ Total deflections $EPSYY$ ($N3$)	0,006	Not-regression
$t=2.0$ Total deflections $EPSYY$ ($N3$)	0.02	Not-regression

Identification	Reference	Type of reference
$t=1.3$ Plastic deformations $EPSYY$ ($N3$)	-0.0104773071226	Not-regression
$t=2.0$ Plastic deformations $EPSYY$ ($N3$)	-0.00505515920024	Not-regression

Identification	Reference	Type of reference
$t=0.8$ Thermal deformations $EPSYY$ ($N3$)	0.0096	Not-regression
$t=1.3$ Thermal deformations $EPSYY$ ($N3$)	0.0156	Not-regression
$t=2.0$ Thermal deformations $EPSYY$ ($N3$)	0,024	Not-regression

Identification	Reference	Type of reference
$t=1.3$ Mechanical deformations $EPSYY$ ($N3$)	-0.0096	Not-regression
$t=2.0$ Mechanical deformations $EPSYY$ ($N3$)	-0,004	Not-regression

5 Summary of the results

The results found with these two modelings are very close, the relative error being lower than 0.02% . For the deformations, the variations are very weak between the modeling B which are used as reference and modeling A. What makes it possible to validate the calculation of the thermal deformations with the metallurgical model.